- the consumption of marine and freshwater dietary resources.

Collagen extraction was undertaken using the procedure outlined in Richards and Hedges (1999). This was modified by the use of ultrafilters (Brown et al 1988), which are used to remove degraded and contaminating molecules under 30 kD. All data presented here have CN ratios within the range 2.9–3.6, which indicates an extraction within acceptable quality limits (DeNiro 1985). All collagen yields are at, or above, 1.8%, meaning that they are all within the yield limits considered indicative of good-quality collagen when ultrafilters are not used (Ambrose 1990). The use of these filters reduces yields, since degraded molecules are removed, so that the yields are considered well within the acceptable range.

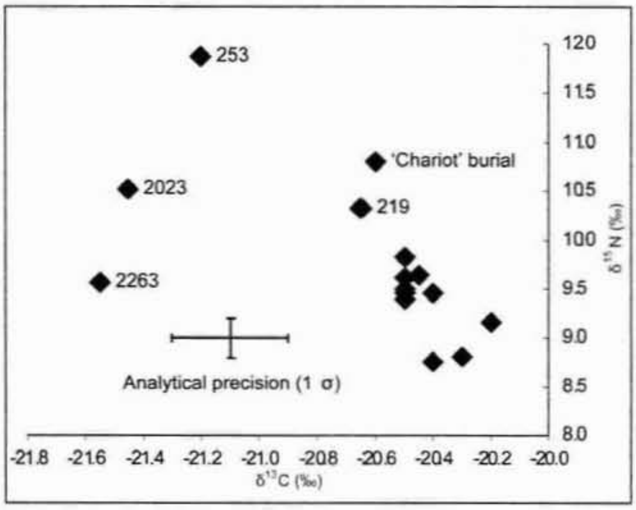

Figure 184: Carbon and nitrogen isotopic data for the humans

Multi-Isotope Analysis

Introduction

Tooth enamel and bone samples from six cattle from the ditch around chariot burial ***2230*** (Site D (Ferry Fryston)), and of 15 human burials from Sites D (Ferry Fryston), Q, M, and XX15, were submitted for isotope analysis. The work was carried out as part of an ongoing Iron Age Isotope Research Project at the University of Bradford, funded by the AHRB, NERC, the University of Bradford, and the Highways Agency.

Bone samples for carbon and nitrogen isotope analysis, and enamel samples for oxygen isotope analysis, were prepared and analysed at the University of Bradford. Strontium isotope data were obtained from tooth enamel samples, which were prepared at the University of Bradford following the method given in Montgomery (2002), and then transferred to the clean laboratory suite at the NERC Isotope Geosciences Laboratory, Keyworth, Nottinghamshire, for chemical separation and analysis. The strontium data for the cattle were obtained as part of an MSc dissertation project at the University of Bradford (Lakin 2004).

Carbon and nitrogen isotope analysis

Mandy Jay

The carbon and nitrogen isotopic values from human and animal bone collagen reflect the diet, particularly that of dietary protein (Ambrose 1993; Sealy 2001). Using such data, it is often possible to draw conclusions about:

- the levels of animal protein (meat and dairy products) in the diet, as compared to terrestrial plant consumption, ie the identification of omnivorous and carnivorous diets;
- the consumption of plants following the C_4 photosynthetic pathway (or protein from animals consuming such plants themselves), as compared to the consumption of C_3 plants;

The 16 human burials dated from the Bronze Age through to the Romano-British period and included the Iron Age chariot burial (Fig 184). The analysis was undertaken on rib samples in the majority (13), with some long bone cortex. Collagen signals reflect average diet over a number of years, as the bone content turns over in the individual, so that the values obtained are for long-term consumption patterns over a lifetime, rather than the short-term childhood signals from tooth enamel seen in the strontium and oxygen analyses.

In order to interpret these data fully, a 'baseline' from local, contemporaneous fauna (particularly herbivores) would normally be required as an indicator of the environmental background. The faunal data available for comparison in this case are from the cattle deposited in the enclosure ditch of the chariot burial, which date to a period some time after that burial, and from unpublished Iron Age data from another study in the area (Booth 2003). Six of the cattle were analysed, and these provided averages of the ratios of ^{12}C-^{13}C ($\delta^{13}C$ of -21.9±0.3‰) and of ^{14}N-^{15}N ($\delta^{15}N$ of 5.9±1.2‰)

compared well with the unpublished faunal data from Booth. Nitrogen values can fluctuate across the UK, depending on local environment (Jay, unpublished Iron Age data). In addition, the possibility that the cattle may have been imported to the area must be borne in mind when using them as a baseline.

Given the faunal data available, the values obtained from the majority of the humans would indicate around one trophic level, with a difference between the average $\delta^{13}C$ for the cattle and Middle Iron Age humans of 1.4‰ and $\delta^{15}N$ of 3.6‰. This indicates an omnivorous diet, with no indication of a C_4 plant input (as would be expected for the UK), or of the consumption of marine foods. Both the human and faunal data are fully consistent with a diet obtained in the UK. The two Bronze Age individuals have values which are noticeably more negative on the carbon scale, and it is possible that this was an environmentally driven differentiation, but no fauna are available for comparison.

Burial *253* from Site XX15 also has a noticeably different signal in terms of both carbon and nitrogen. Radiocarbon assay has placed this individual, represented by a disarticulated skeleton, in the Late Iron Age (*see Ch 3, p 75*). The differences might represent an unusual pattern of consumption, but the differentiation could also result from differing environments, either over time or across space (if this was a mobile individual). If not an incomer to the site, it is possible that the data suggest freshwater fish were a major contribution to the individual's diet.

Oxygen isotope analysis

Vaughan Grimes

The oxygen isotope ratio of mammalian bone and tooth enamel phosphate ($\delta^{18}O_p$) is related to oxygen isotopes in precipitation ($\delta^{18}O_{precip}$) through drinking water, and the $\delta^{18}O_{precip}$ signal is strongly influenced by environmental and geographic parameters such as air temperature, latitude, distance from the coast, and altitude (Dansgaard 1964). As such, the $\delta^{18}O_p$-$\delta^{18}O_{precip}$ relationship has been widely used by researchers as a tool to reconstruct past climates (Genoni *et al* 1998; Longinelli 1984; Luz and Kolodny 1985) and, increasingly, to detect human and animal migration (White *et al* 2004). By analysing the $\delta^{18}O_p$ value in tooth enamel, which incorporates an environmental signal during early life, and comparing it to the $\delta^{18}O_{precip}$ value in local rainfall, it may be possible to determine whether or not an individual has moved, during their lifetime, between geographical regions that have different $\delta^{18}O_{precip}$ signatures (Fig 185).

In the present study, phosphate oxygen isotope analysis was carried out on tooth enamel from 12 individuals, in order to determine whether they spent their childhood in or near the region in which they were buried. Enamel sections representing the entire tooth crown were removed from permanent molar and premolar teeth and mechanically separated from dentine. They were powdered in a stainless steel mortar and pestle before being treated with 2.5% sodium hypochlorite to remove possible organic contaminants. Phosphate was then extracted as silver phosphate according to the method described in Dettman *et al* (2001).

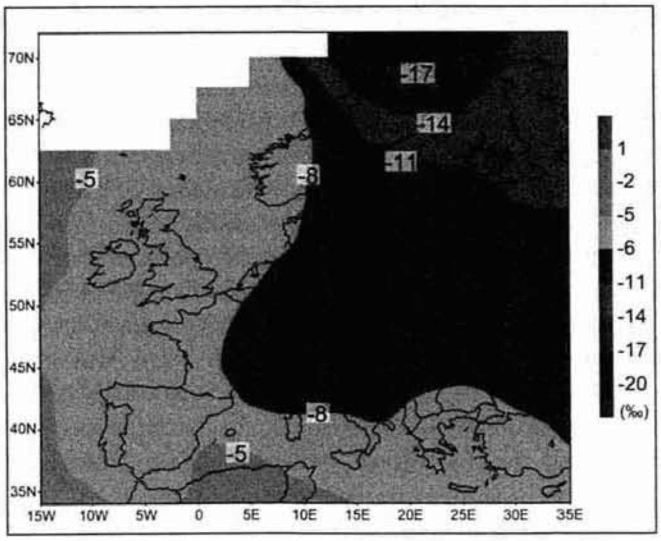

Figure 185: Representation of the weighted annual oxygen isotope signal in precipitation for Europe

Results from the oxygen isotope analysis were plotted, together with the strontium isotope ratios (Fig 186). Although conclusions from the oxygen isotope data remain tentative, several observations can be made.

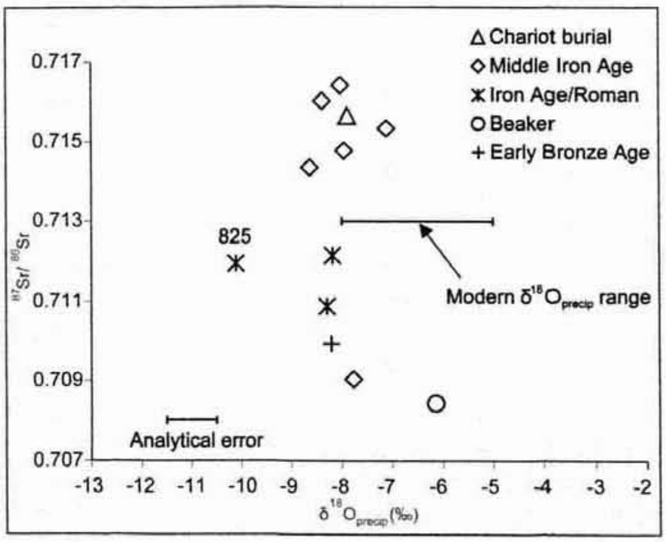

Figure 186: Oxygen and strontium isotope ratios in tooth enamel

With the possible exception of individual *825* (Site Q), the range in oxygen isotope values is relatively restricted, around a mean value of -7.8‰ ± 0.7 (1σ). When coupled with the analytical error, these values are consistent with modern annual $\delta^{18}O_{precip}$ for a region between 10° E latitude and 10° W latitude, or most of current Western Europe (Fig 185). Therefore, it is likely that 11 of the 12 individuals sampled for oxygen isotope analysis spent at least part of their childhood in this region.

Secondly, there does not appear to be any clear relationship between the oxygen and strontium isotope ratios from these samples, nor are there obvious 'cultural' or 'temporal' divisions within the oxygen isotope results as reflected in the strontium data for some of the Middle Iron Age individuals and the individual from the chariot burial. It is important to note that correlations between strontium and oxygen isotope ratios are not necessarily expected, as they are influenced by mutually exclusive variables. Finally, the $\delta^{18}O$-depleted (more negative) enamel from individual *825* (Iron Age/Romano-British period) might indicate that this person spent part of their childhood in an area outside the region.

Strontium isotope analysis

Janet Montgomery, Kay Lakin, and Jane Evans

Human mobility can be investigated by analysing the strontium isotope values of tooth enamel, which mineralises in early childhood (*eg* Cox and Sealy 1997; Ezzo and Price 2002; Montgomery *et al* 2003; Price *et al* 1994; Price *et al* 2002). If a difference can be demonstrated between the enamel and that of locally available values obtained from rock, soil, plants, and other humans and animals believed to be of local origin, an individual is deemed to have either originated elsewhere, or to have consumed a (childhood) diet composed predominantly of imported food. However, the age at which they moved is difficult to establish if the move was after enamel mineralization was complete (*ie* around puberty). Tracking the mobility of adults is further thwarted, because the integrity of strontium isotope ratios obtained from other later-forming skeletal tissues such as bone and dentine cannot currently be established (Trickett *et al* 2003).

Strontium isotope data were obtained from six of the cattle from the ditch of the chariot burial (designated cow 1, cow 2, *etc*) in order to determine if they were from the same herd and whether they were of local origin. Information was also obtained from the tooth enamel of 12 humans, dating from the Bronze Age through to the Romano-British period, which had been subject to oxygen isotope analysis (*see above*).

The cattle show a very wide range of strontium isotope values (0.71-0.72) that greatly exceeds the variability observed in a single herd of modern cattle (Lakin 2004), and is not consistent with a diet obtained from rainwater and plants grown on the local Magnesian Limestone (McArthur *et al* 2001; Fig 187). This suggests that the cattle were not raised together in the same herd, and were not grazed on limestone pasture during the first year of life, which is when the teeth analysed in this study (second mandibular molars) would have mineralized (Brown *et al* 1960). Therefore, the isotope data suggest that either the cattle came from disparate and varied locations, before or after slaughter, or, perhaps less probably, that the bulk of their diet consisted of imported food.

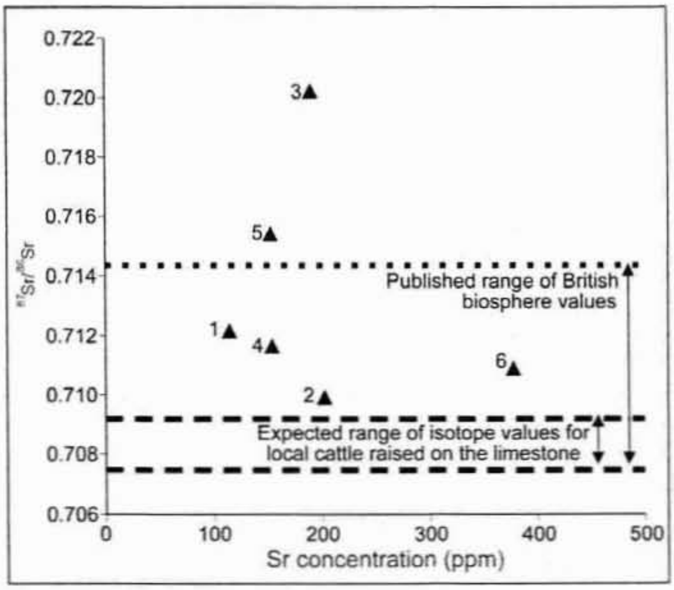

Figure 187: Strontium data for the second mandibular molars of six Romano-British cattle from Site D (Ferry Fryston)

The narrow ridge of limestone which the route of the A1 follows is bounded to the east by Permo-Triassic mudstones and sandstones, and to the west by the sandstones of the Upper Carboniferous Coal Measures (*see Ch 1*), which can provide biosphere strontium isotope values between 0.709 and 0.714 (unpublished data held by Montgomery and Evans). The strontium values seen in cattle 1, 2, 4, and 6 might thus be explained by origins in Yorkshire, although this does not rule out origins elsewhere in Britain or the Continent, where such values may also be obtained. Cattle 3 and 5 have strontium isotope values that have not been observed to date in British archaeological animal or human samples (Budd *et al* 2000; Evans and Tatham 2004; Montgomery 2002; Montgomery *et al* 2000; 2003; 2005). Such values are indicative of origins in regions of ancient granites and gneisses (*eg* Åberg 1995; Grupe *et al* 1997; Muller *et al* 2003; Negrel and Pauwels 2004; Sillen *et al* 1998), which do not occur in significant amounts in England or Wales (British Geological Survey 1979a; 1979b).

The humans also exhibit a wide range of strontium isotope values (~0.708-0.716) (Fig 186). The Beaker burial (*2263*), a female Middle Iron Age burial (*732*), and possibly the Early Bronze Age individual (*2023*) are consistent with local origins, *ie* within range of seawater (the source of rainwater) and the Magnesian Limestone (McArthur *et al* 2001). However, such values would also be consistent with origins on other marine carbonates such as Cretaceous Chalk.

The two Iron Age/Romano-British burials from Site Q (*825* and *742*) have similar strontium values, despite having different oxygen isotope ratios. Such strontium values are not indicative of origins on limestone. Nevertheless, comparable values have been obtained from other human burials in Yorkshire and elsewhere in southern and eastern England (*eg* Montgomery 2002; Cooper 2004), as well as in cattle 1 and 4.

The final group has high strontium isotope ratios, and contains only Middle Iron Age individuals from Site M and the chariot burial. As already noted for the cattle, such high values are indicative of origins in regions of old granites and gneisses and exceed the current range of published archaeological human enamel data from Britain (Fig 187). Moreover, similar values are only rarely reported in datasets of archaeological tooth enamel outside Britain (*eg* Sillen *et al* 1998; Grupe *et al* 1997; Price *et al* 2002). Consequently, there is currently very little comparative data for archaeological humans or animals against which to compare these individuals and draw sound conclusions about their origins.

Conclusions

Combining the evidence available from the suite of isotopes with the overall archaeological context, it is difficult to draw firm conclusions that aid current understanding of the possible movements of Iron Age people across Europe. The results contribute to ongoing research and may help to elucidate questions generated by the recent work, including how long the cattle spent in the Ferry Fryston area prior to death, the contribution of drift of Scandinavian origin to biosphere values in East Yorkshire, and potential sources of origin for the Middle Iron Age human burials and the two cattle of 'exotic' origin.

Sample/ Context	Description	*Alnus*	*Betula*	*Corylus*	*Fraxinus*	*Ilex*	Pomoideae	*Prunus*	*Quercus*	*Populus/ Salix*	*Ulex/ Cytisus*	*Ulmus*	*Pinus*
						Early Bronze Age							
						Site D (Ferry Fryston)							
Sample 1, fill *2060*	Cremation pit *2061*, within ring ditch ***2068***	Insufficient charcoal for identification											
Sample 2, fill *2134*	Fill (segment *2133*) in outer ring ditch ***2121***	-	-	2	1	-	-	-	1s, 2u	-	-	-	-
Sample 4, fill *2144*	Cremation pit *2145* at centre of ring ditch ***2121/2122***	-	-	-	-	-	5	-	1h, 7s, 2u	-	-	-	-
Sample 7, fill *2148*	Fill (segment *2149*) in inner ring ditch ***2122***	-	-	-	-	-	-	-	*cf* 1u	-	-	-	-
						Middle Iron Age							
						Site M							
Sample 6, fill *121*	Human burial *120*, in *122*	-	-	*cf* 1	-	-	-	-	8h, 8s	-	1	-	-
Sample 7, fill *100*	Fill, pit *99*, adjacent to roundhouse ***126/1220***	-	-	3	-	-	-	-	3u	-	-	-	-
Sample 66, fill *1410*	Fill, post-pit *1408*, four-post structure ***2070***	-	-	-	-	-	-	-	-	-	-	-	179
Sample 110, fill *2578*	Fill, pit *2058*, associated with articulated cow burial *2100*	-	3	1	-	-	2	-	1u	-	-	-	-

Table 62: Charcoal analysis